Space Technology Research Grants

Commanding and Planning for Robots in Space Operations

Completed Technology Project (2017 - 2021)

Project Introduction

Autonomous and semi-autonomous systems like unmanned spacecraft or robotic vehicles have filled critical roles in NASA's great successes, surviving the harsh environs that lie outside Earth's protective atmosphere. Beyond robotic missions today, NASA is investigating robots that have capabilities similar to humans, such as NASA's research platforms Robonaut 2 (R2) and Valkyrie. Robots like R2 and Valkyrie could provide sustainable, persistent care of infrastructure and equipment while there are humans present and when not. A future robotic team could lay the groundwork for human arrival on Mars, freeing precious time for scientific mission goals. This proposal aims to design an interface and the technology necessary to formulate and plan for complex tasks on complicated, humanoid robots operating in space. An example of an application of such a system is in dormancy operations for long-term space exploration. In the future, an operator for a robot managing a habitat may need to accomplish some task, such as moving cargo from one module of the habitat to another. The operator would observe the robot, establish parameters and constraints of the plan, and request a plan. To exert finer control over the robot's motions, the operator could add more complex constraints. The system would generate a plan that respects constraints, possibly drawing upon previous plans to suggest improvements, and then display the motion and relevant statistics to the operator for approval. If a problem occurs, the operator can rest assured that there is a contingency in place so that the robot can safely recover, and begin planning anew. To achieve this vision, many fields of active robotics research need to be drawn from. Foundational research must be done for disparate problems in robotics as to integrate them into a whole, usable system. Humanoid robots benefit from their form as they may utilize the same tools and environment as humans, but accounting for their formidable mechanical capability while planning is a hard task. To achieve tasks in spaces designed for humans, the robot must respect constraints imposed from the tools used and intrinsic details of the navigable space. Sampling-based constrained motion planners are a promising approach to solve problems of this nature. However, contemporary constrained motion planners do not generalize to arbitrary, complex combinations of constraints. To this end, the proposed work includes development of a rigorous mathematical model of general constraints that can be leveraged by a novel constrained motion planner for effective motion planning. For a robot to remain safe while executing motions, the inherent uncertainty in the world must be accounted for, through planning under uncertainty. This proposal will investigate integration of constrained planning with contingency planning, as to have readily available motions to bring the robot back to safety in the event of failure. For safety and accountability, operators must also have feedback from the planning process to iteratively refine and eventually approve motions for execution. Approved plans will then be stored for later reuse as to not repeat previous efforts, using experience-based planning and cloud robotic systems to synchronize robotic teams. Possible improvement of stored knowledge through geometric and optimal

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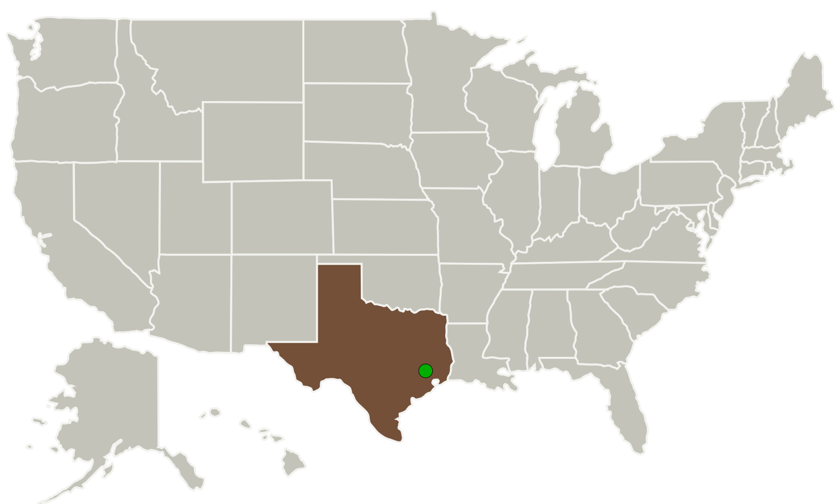
planning techniques will also be investigated. A robotic agent that could be accurately and safely commanded aligns significantly with NASA's goals for autonomous agents and further long-term space exploration. Although this proposal focuses on humanoid robots in space operations, the ideas and techniques presented are general, and widely applicable to other systems that must plan and require human operation. Methods from this proposal could be applied to other systems such as configurable habitats, rovers, and assistive or household robotics back on Earth.

Anticipated Benefits

A robotic agent that could be accurately and safely commanded aligns significantly with NASA's goals for autonomous agents and further long-term space exploration. Although this proposal focuses on humanoid robots in space operations, the ideas and techniques presented are general, and widely applicable to other systems that must plan and require human operation. Methods from this proposal could be applied to other systems such as configurable habitats, rovers, and assistive or household robotics back on Earth.

Primary U.S. Work Locations and Key Partners



Organizational Responsibility

Responsible Mission Directorate:

Space Technology Mission Directorate (STMD)

Lead Organization:

Rice University

Responsible Program:

Space Technology Research Grants

Project Management

Program Director:

Claudia M Meyer

Program Manager:

Hung D Nguyen

Principal Investigator:

Lydia Kavraki

Co-Investigator:

Zachary K Kingston

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Organizations Performing Work	Role	Type	Location
Rice University	Lead Organization	Academia	Houston, Texas
Johnson Space Center(JSC)	Supporting Organization	NASA Center	Houston, Texas

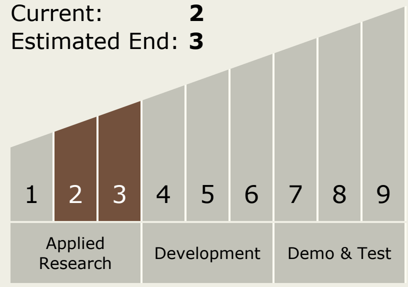
Primary U.S. Work Locations
Texas

Project Website:

https://www.nasa.gov/strg#.VQb6T0jJzyE

Technology Maturity (TRL)

Start: **2**
Current: **2**
Estimated End: **3**



Technology Areas

Primary:

- TX10 Autonomous Systems
  └ TX10.2 Reasoning and Acting
    └ TX10.2.4 Execution and Control

Target Destinations

Mars, Others Inside the Solar System